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the freshest pieces but scattered through these are numerous grains of a partially decomposed mineral, which is doubtless olivine. Probably it is the decomposition of this mineral which forms the metallic portion of the more altered slides. One interesting feature of the fresher porphyrite is the fact that the interstitial augite which acts as the matrix for the feldspar individuals, extinguishes simultaneously over quite large areas, a fact which has been observed in both granites and gabbros as well as in the fresher portions in the so called mottled melaphyr of Pumpelly, here in the northwest.

April 2, 1889.

[*Paper FF.*]

THE IRON BEARING ROCKS OF MINNESOTA.—*H. V. Winchell.*

[*ABSTRACT.*]

After speaking of the mining industries of northeastern Minnesota and pointing out on a chart some of the geographic and geologic features of our state Mr. Winchell continued :

The oldest formation in which we find iron bearing strata is the crystalline schist series, called the Vermilion series by the Minnesota geologists.

This formation consists of mica and hornblende schist strata, which spread over a large part of northeastern Minnesota. On the shores of Pelican lake, Rainy lake, Namekan lake, Vermilion lake and many others of our largest bodies of water, there are extensive out-crops of these rocks. Their dip is at all angles, from horizontal to vertical, but generally the latter. However, on Rainy lake several anticlinals are seen, where the dip changes from south to north, or vice versa. The general trend or strike of this formation is that of all the stratified rocks of the region, *i. e.*, about north, sixty degrees east.

It is only very recently that this formation has been proved to be iron-bearing. But during the past few months samples of good ore have been obtained from it in township 63 N., Range 12 W., north of the town of Ely. In sections 4 and 5 of this township the hornblende schist becomes charged with magnetite to such a degree that it is apparently a fair quality of magnetic ore. No analyses have yet been made of it. It may contain titanium.

It is not at all unlikely that this formation may prove to be of great value as an iron-producing horizon in Minnesota, since many productive mines are situated in the same rocks in New York and Canada.

Next younger than the Vermilion series is the Keewatin. This formation was first described under this name (which means "north") by Mr. A. C. Lawson of the Canada geological survey, who studied it on Lake of the Woods. It consists of vertically-bedded green schists and slates, which are in places hydro-micaceous and have a soft, greasy feel. The Keewatin appears to grade insensibly into the older crystalline schists, which are found between it and the granite on both sides. It is largely composed of eruptive material which has been re-arranged and re-deposited in water. In it are found peculiar agglomerate schists in which the pebbles are of the same green diabasic material as the magma which surrounds them.

In this formation are found the wonderfully pure and extensive deposits of specular iron ore, which have made the Lake Superior region famous. In fact, the only mines that have been really worked in this state are in the Keewatin, at Tower and Ely. The ore is largely hematite, but contains some magnetite in places. It is very hard, as a rule, and the cost of explosives is no small item in the mining expenses. At the Minnesota mine, for instance, there was used in the month of July over 30,000 pounds of dynamite and powder, and 1,300 men were employed to drill, break up and handle a quantity of ore not very much greater than was mined by half that number of men at the Chandler mine where the ore is in a crushed or brecciated condition.

The ore beds are in vertically placed lens-shaped masses, and are mingled with or accompanied by large amounts of banded red, white, black and gray jasper. So intimately mixed are the ore and jasper rock or "jaspilite" as it is called, that much of it is worthless. But at many places there are deposits 100 feet long, 30 to 90 feet wide and of indefinite depth where the ore contains on an average less than 2 per cent. of all impurities and that mostly silica. Its particular value lies in its low content of phosphorus, averaging less than one-tenth of one per cent. For this reason Minnesota ore is in great demand by the manufacturers of Bessemer steel.

While speaking of the mines in the Keewatin formation it will not do to omit mention of the Chandler mine at Ely, which

may fairly be considered the most wonderful mine in the world.

It has only forty acres and works but a small part of that. It is only fifteen months since the first work was done on the wooded hillside, now covered by shaft houses, hoisting machinery and railroad tracks. And in that short space of time nearly 300,000 tons of iron ore have been mined and shipped by rail to Two Harbors, and thence by boat to Cleveland and other points.

Considering the area covered by the mine, this is a record never before equaled, and chief credit is due to the superintendent and general manager, Capt. Joseph Sellwood of Duluth, who has put into operation a very simple but efficient method of mining rapidly and cheaply.

The next formation which contains workable deposits of iron ore is the Huronian, which lies unconformably upon upturned edges of the Keewatin. In this formation we find sedimentary slates and quartzites interbedded with some gabbro and greenstone.

In the vicinity of Gunflint lake, on the international boundary, this formation is found to contain deposits of granular, shiny magnetite, more or less mixed with quartz and olivine. Hematite ore is found in this same formation in connection with the red and gray quartzite of Pokegama Falls near Grand Rapids, on the Mississippi river above Aitkin. At this locality is the most western outcrop of iron ore-bearing strata in the state.

In this same Huronian formation are situated some of the mines of northern Wisconsin and Michigan. The Penokee-Gogebic range is composed of rocks of this age. We may therefore confidently expect to find profitable deposits of ore in this state in many places where it is now unlooked for and unexpected.

This ore is more regular in its manner of deposition than that of the Keewatin. It is in beds interstratified with quartzite, all having a general dip in this state of perhaps fifteen degrees to the southeast. This quartzite is supposed to be the upper part of the Huronian and to lie unconformably on the slates beneath.

Next in order above the Huronian is found the gabbro, which has been erupted and has flowed over the top of the Huronian strata, in some places entirely concealing them from sight, burying them under 200 or 300 feet of gray igneous rock, and in others, breaking up the Huronian quartzites and surrounding masses in areas a half mile or more in extent.

The iron ore found in the gabbro is unquestionably of igneous origin. It is a dull, massive magnetite with feebler magnetic attraction than the shiny granular ore of the Huronian quartzites. It also differs from the latter in containing titanitic acid, ranging from 1 to 30 per cent. Although it is found in mountains which would be almost inexhaustible were they mined, the titanitic acid renders the ore undesirable with the present methods of iron smelting. Where beds of the ferruginous Huronian quartzites are found involved in the gabbro overflow, as mentioned above, we seem to have non-titaniferous magnetite from the gabbro itself, but the appearance of the ore generally shows its true nature; and it may be stated as a general truth that the gabbro magnetite is titaniferous.

Ascending now through geologic time past all the rocks of the Silurian, Devonian and Carboniferous, we find our last iron ore formation to be the Cretaceous. At the bottom of this formation are found beds several feet thick of a low grade limonite ore. It occurs in Fillmore county, where the Cretaceous lies upon the Lower Magnesian, and is reported to be more than thirty feet thick in places. Some of this ore has been used at the furnace at Black River Falls, Wisconsin. It is probably of as good quality and as extensive in quantity as much of the ore formerly mined and smelted in Pennsylvania. But as long as we have mines in the northern part of our state of the best ore in the world, the poorer Cretaceous ore of the southern part of the state will not be used.

October 8, 1889.

[*Paper GG.*]

CRYPTOZOON MINNESOTENSE IN THE SHAKOPEE LIMESTONE AT NORTHFIELD, MINNESOTA.—*L. W. Chaney, Jr.*

Several years ago I noticed frequently what appeared to be curved strata in the Shakopee limestone at a point near Northfield. A carriage road passed along under the ledges near the river so that one traveling that way could scarcely fail to notice the peculiar arrangement. After puzzling somewhat over them, attention was called elsewhere and a railroad having usurped the place of the former carriage road, they were seen but little and forgotten.

Two years ago Mr. F. O. Higbee and Mr. W. S. Wingate of the junior class in Carleton College were prospecting for fossils